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August 9, 2015

Dr. Robert Headrick
ONR Code: 332
Office of Naval Research
875 North Randolph Street
Arlington, VA 22203-1995

Dear Dr. Headrick,

Attached please find the progress report for ONR Contract N00014-14-C-0230 for the period of January 20, 2015 to April 19, 2015.

James C. Preisig
President, JPAnalytics LLC

CC: DCMA Boston
DTIC
Director, NRL

Report Documentation Page

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Progress Report #4

Coupled Research in Ocean Acoustics and Signal Processing for the Next Generation of Underwater Acoustic Communication Systems

Principal Investigator's Name:	Dr. James Preisig
Period Covered By Report:	1/20/2015 to 4/19/2015
Report Date:	8/9/2015
Contract Number:	N00014-14-C-0230
Firm Name and Address:	JPAnalytics LLC 638 Brick Kiln Road Falmouth, MA 02540 jpreisig@jpanalytics.com (508) 566-0236
Program Officer:	Dr. Robert Headrick ONR Code: 322 Office of Naval Research 875 North Randolph St. Arlington, VA 22203-1995 Robert.Headrick@navy.mil
Security Classification:	Unclassified
Distribution Statement:	Approved for public release. Distribution is unlimited.
Total Contract Amount:	$595,731
Costs Incurred This Period:	$57,815
Costs Incurred To Date:	$143,486
Estimated Costs To Complete:	$452,245

1. **Description:** Technical work this period has spanned five areas. The first was continuation of work on developing a methodology within the framework of asymptotic random matrix theory (RMT) to explicitly model the time variability of acoustic channels and using this to predict underwater acoustic communications systems performance. Prior methods have accommodated time variability by assuming that the channel is time invariant over an appropriately short interval of time. By explicitly modeling the time variability within the RMT framework it is hoped that the resulting analysis will more accurately predict the trade-offs associated with the rate of channel fluctuations, the number and configuration of hydrophone array elements, the size of filters in subsequent equalizers, and the structure of the equalizer adaptation algorithms. In this work, the channel variability is represented by the Delay-Doppler spread function denoted by $U(\epsilon, \nu)$ as described in Progress Report #3 for the period of October 20, 2014 to January 19, 2015. The full expressions are complex and make the development of insights difficult. Thus, the current effort is focused on deriving simplified expressions to enable the development of insights while still capturing the most important features of the problem. This work falls under Research Task 1 from Section 2.2 of the Technical Approach and Justification.

   During this time period, the Principle Investigator continued work on evaluating the correlation structure of received communications signals after they have been converted to the frequency domain via Fourier Transforms as described in Progress Report #3 for the period of October 20, 2014 to January 19, 2015. The work is lending insights that will help explain how the signal correlation structure will depend on either the non-linearity or non-stationarity of the channel fluctuation and guide both algorithm design and performance prediction algorithms for underwater acoustic communication systems. This work falls under Research Task 3 from Section 2.2 of the Technical Approach and Justification.

   During this time period, the Principle Investigator has also worked on both structured graphical based techniques and iterative Expectation Maximization (EM) based approaches to exploiting structure in the correlation of the received communications signals. This work is related to and exploits the results of the work described in the preceding paragraph. This work falls under Research Task 3 from Section 2.2 of the Technical Approach and Justification.

   During this time period, the Principle Investigator has also begun work on evaluating a channel compression pre-processing approach to simplifying and im-

proving the performance of adaptive multi-channel equalization systems. The two-stage pre-processing approach can utilize the computational efficiency of lattice based adaptive time-domain filters to individually process the receptions prior to joint adaptive processing by a simplified adaptive multi-channel equalizer. Various simplifications of the first stage processor including parallel implementation of sample offset symbol rate equalizers were investigated. The work was taking through an initial investigation stage. Follow-on implementation and performance evaluation will be pursued at a later date. This work falls under the general area of improvements in adaptive channel equalization which is part of Research Objective 3 in Section 2.1 of of the Technical Approach and Justification.

During this time period, the Principle Investigator prepared for the first in a series of VHF acoustic experiments (the first one being in a wave tank) with Dr. Grant Deane at the Scripps Institution of Oceanography. This work falls under Research Task 2 from Section 2.2 of the Technical Approach and Justification.

During this time period, the Principle Investigator also attended the Navy's Unmanned Undersea Systems Technology program review in Sandestin, Florida and prepared for, attended, and presented a talk at the ONR Ocean Acoustics Program review at Naval Research Laboratory, Stennis.

2. **Major Accomplishments this Period:** The work on graphical and iterative EM based techniques has enabled algorithms to be implemented which both lend themselves to easy parallelization and achieve significant reductions in computational complexity when compared to standard least squares based adaptive equalizers.

3. **Results and Recommendations:** None

4. **Publications and Presentations:**

   A. Yellepeddi, J. Preisig, "Adaptive Equalization in a Turbo Loop", revised, resubmitted to, and accepted for publication in the *IEEE Trans. on Wireless Communication*.

   M. Pajovic, J. Preisig, "Performance Analytics and Optimal Design of Multichannel Equalizers for Underwater Acoustic Communications", revised for resubmission to the *IEEE Journal of Oceanic Engineering*.

J. Preisig, "Underwater Acoustic Communications: Enabling the Next Generation at the Intersection of Ocean Acoustics and Signal Processing", at the ONR Ocean Acoustics Program Peer Review, April 7-8, 2015.